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"Synthesis of Systemic Functional Theory & Dynamical Systems Theory for Socio-Cultural Modeling"

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Note: Kevin Judd was on extended medical leave in 2011. He did not contribute to the project during 2011-2012, which both delayed and compromised the development of the mathematical tools. Dr Christel-Loic Tisse (former Senior Research Fellow, Multimodal Analysis Lab, National University of Singapore) was employed as consultant from April 2011-June 2011, Dr Vahan Hovhannisyan was the scientific researcher from September 2011-April 2012 and Dr Alexey Podlasov (Research Fellow, Multimodal Analysis Lab, National University of Singapore) contributed to the project. Marissa E Kwan Lin was the Research Associate for the project.

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14. ABSTRACT
This is the final report of a project that has shown conclusively that mathematical modeling of complex data structures arising multimodal analysis of multimedia texts has potential for describing, identifying interpreting and forecasting socio-cultural patterns trends and instabilities through the identification of semantic patterns which are specific to different people, texts and situational contexts.

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Abstract

This project has shown conclusively that mathematical modeling of complex data structures arising multimodal analysis of multimedia texts has potential for describing, identifying interpreting and forecasting socio-cultural patterns trends and instabilities through the identification of semantic patterns which are specific to different people, texts and situational contexts. The complex data structures are derived systemic functional theory (SFT) where linguistic, visual and audio resources are conceptualized as integrated systems of meaning. The approach moves beyond text analytics where concepts are derived from lexical choices to a holistic approach that takes into account the meaning arising from the interaction of language, images and audio resources. The approach has significant implications for discourse analysis, data mining, search and retrieval and visual analytics which currently lack theoretical frameworks to account for the interaction of language with other resources in texts.

1. Introduction

The aim of the project is to apply methods and principles of dynamical systems theory (DST) to base data derived from systemic functional theory (SFT) analysis of text and multimedia resources, with the aim of identifying and tracking evolving semantic patterns, in particular those related to stability and instability. The goal of the project is to develop theory and algorithms, and demonstrate their validity and potential with case studies involving multimodal analysis of linguistic, visual and audio choices in multimedia texts.

Detailed SFT analysis of six case studies provided test-case base data for DST analysis in the first phase of the project. The case studies involved online discourses about the global financial crisis and climate change, with a focus in the events occurring around the time of the United Nations Copenhagen Climate Change Summit 2009 (COP15) in Copenhagen, Denmark on 7-18 December 2009. The focus shifted to written texts and televised interviews about the Climatic Research Unit email controversy involving the hacking of a server at the Climatic Research Unit at the University of East Anglia on 20 November 2009 in the second and third phases of the project. The Climatic Research Unit email controversy involved extensive media coverage where questions were raised about scientists' manipulation of climate data, as illustrated in the written texts and video segments under analysis.

Software tools for manipulation, analysis, and visualization of the SFT base data for text and video analysis were developed in order to map the 'landscape' on which the dynamics of the texts play out. This involved visualizing and understanding the distribution of information of high dimensionality. Standard mathematical methods of mapping were applied to the SFT base data, such as principle component analysis, local linear embedding, recurrence analysis, and clustering. These preliminary experiments determined both the identifying features of the texts and what existing mapping methods are most useful, before techniques for capturing the dynamics of time-stamped multimodal SFT data were developed in the final phase of the project.

The importance of the research is the development of theoretical approaches and mathematical techniques which take into account the semantic interaction of language, images and audio resources in multimedia texts. At present, data analysis techniques tend to focus solely on language, image and audio analysis in isolation. In this project, these resources are considered as inter-related semantic systems which work together to create meaning in multimedia texts which function inter-textually (i.e. with other texts) to create trends and potential instabilities in society and culture.

2. Experiment

2.1 Systemic Functional Theory (SFT) for Multimodal Analysis

In Systemic Functional Theory (SFT), language and other multimodal resources (i.e. visual, auditory, kinesthetic and spatial resources) are conceptualized as inter-related semantic systems which realize four metafunctions (e.g. Halliday 1978; Halliday & Matthiessen 2004; Kress & van Leeuwen 2006; Martin 1992; O'Toole 2011). The four metafunctions are concerned with (a) experiential meaning: to construct our ideas about the world; (b) logical meaning: to establish logical relation in that world; (c) interpersonal meaning: to enact social relations and create a stance towards the ideas which are expressed; and (d) textual meaning: to organize the message. Experiential and logical meanings are grouped under 'ideational meaning' which is our ideas about the world.

Choices from the various systems for language, image and audio resources work together in multimedia texts to engage and orientate readers to particular views of the world. SFT provides a comprehensive conceptual framework for analyzing informational content (configurations of agents, participants, processes and circumstances), the social relations which are established (power, status and emotion), the orientation to the ideas which are presented (modality and truth value), and the ways in which the choices are organized to achieve specific purposes (e.g. points of departure, given and new information) [1], [2]. SFT provided the base data for mathematical analysis in the project.

2.2 Software Tools

2.2.1 Systemics Software

The main tool for creating the SFT base data in the first two phases of the project was the Systemics software, developed by Kay O'Halloran and Kevin Judd in 1999-2002 for research and teaching SFT. The original Systemics software provided a cross-platform Graphical User Interface (GUI) application for SFT annotation of text at the rank of word group, clause, clause complex, and discourse. These annotations are stored in a database. The software provided basic search functions based on tag count frequencies.

The Systemics software was extensively revised and extended for this project by adding new annotation features, more sophisticated search features, and scientific visualization techniques. The new annotation features allow better analysis of embedded clause structures, discourse chains and lexical items. The new search features in Systemics include word-tag concordances, complex pattern-matching, and complex logical relations of tags across systems and different databases. The new visualization features in Systemics combined mathematical techniques for feature extraction, correlation analysis and cluster analysis. The GUIs in Systemics for clause, clause complex and discourse annotations are displayed in Figures 1(a)-(c).

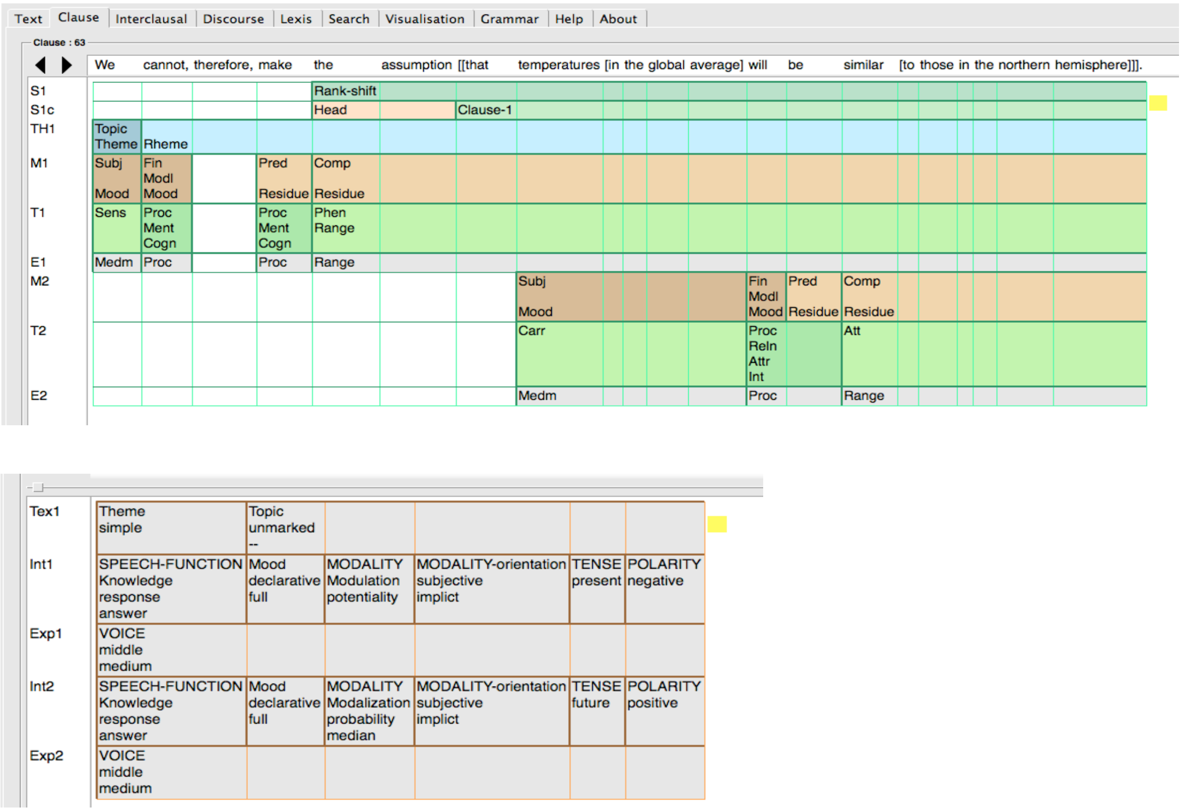


Figure 1(a) SFT Clause Annotation

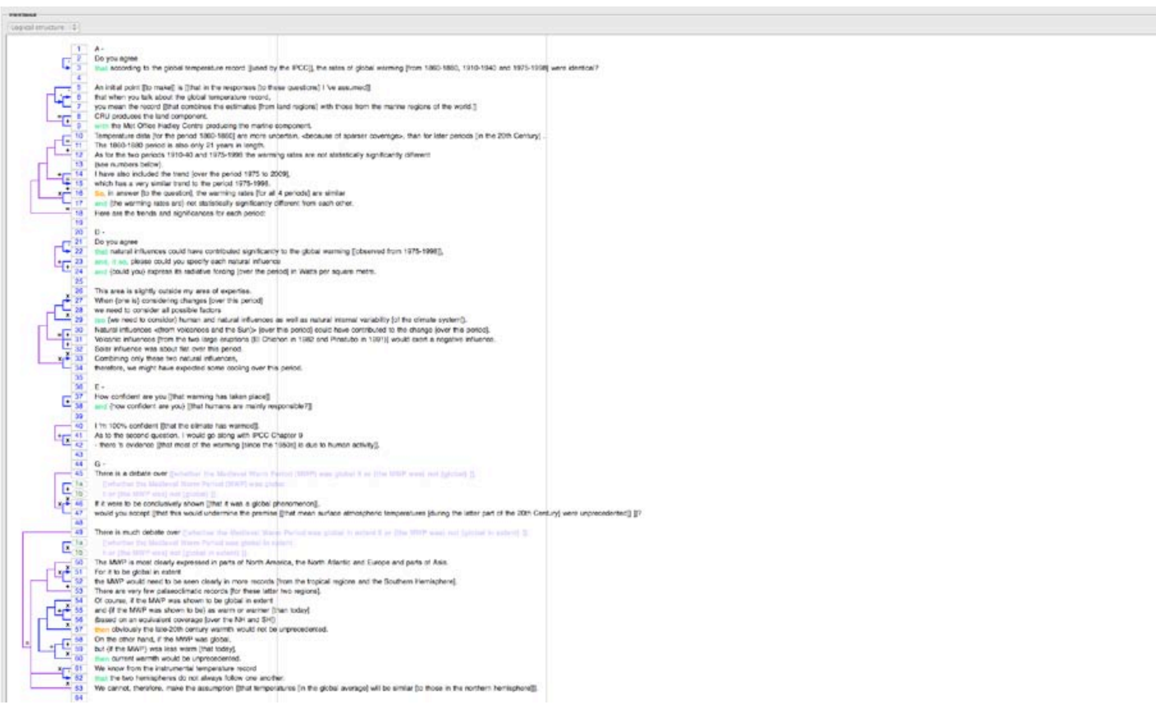


Figure 1(b) SFT Clause Complex Annotation

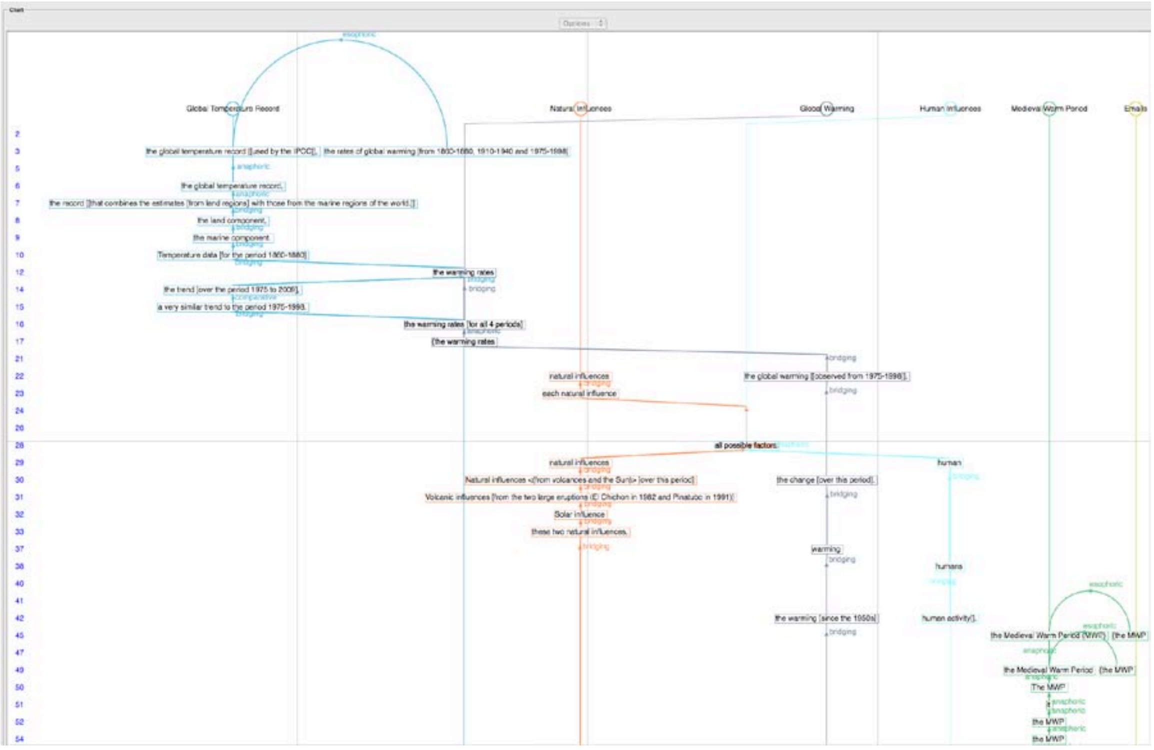


Figure 1(c) SFT Discourse Annotation

In the third phase of the project, the multimodal analysis software developed in the Multimodal Analysis Lab, Interactive & Digital Media Institute (IDMI) at the National University of Singapore permitted linguistic analysis to be integrated with visual and audio analysis to generate time-stamped SFT multimodal data for video texts [3].

2.2.2 Multimodal Analysis Software

The complexity of multimodal analysis, involving language, image and audio resources, requires a range of tools for the annotation, analysis, search and retrieval of semantic patterns in unified but complex semiotic acts; for example, the interaction of language, intonation, gesture, gaze, and camera angle in videos (O'Halloran, Tan, Smith & Podlasov 2011; Smith, Tan, Podlasov & O'Halloran, 2011) The multimodal analysis software is organized into three components to fulfill these requirements: sets of media files, SFT systems used in the annotation, and the annotation units with time-stamped and spatial co-ordinates. The analyst imports the media file and uses a pre-defined set of annotation systems and/or their own set of descriptors and free text to annotate the media by creating nodes in strips with pre-assigned systems for time-stamped analysis and overlays for spatial analysis. The analyst selects the required system choice from the menu of available options and/or inserts free text. The selected option and/or text are stored in a database for later retrieval and export for mathematical analysis.

The GUIs and the assorted tools and facilities (A, B, C etc) in the multimodal analysis software for annotating video and sound, text time-stamping and annotations are displayed in Figure 2(a)-(c).

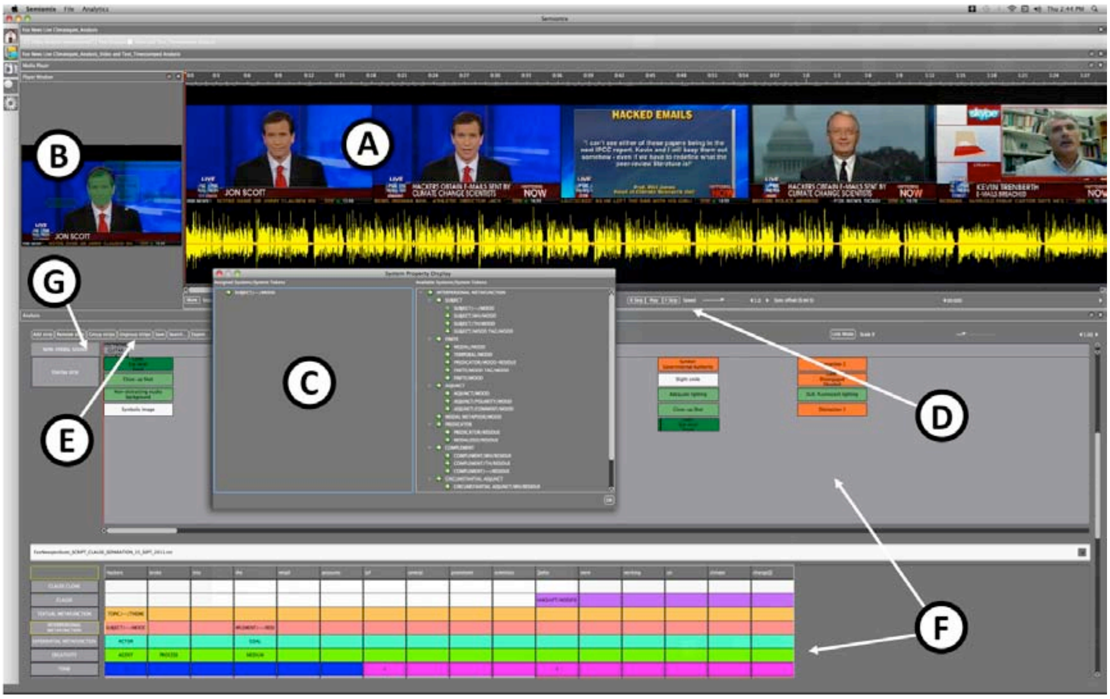


Figure 2(a) Sound and Video Annotation GUI

(A) Filmstrip and waveform area; (B) Player window; (C) Systems Choice window; (D) Playback controls; (E) General controls; (F) Annotation strip area; (G) Strip organization view

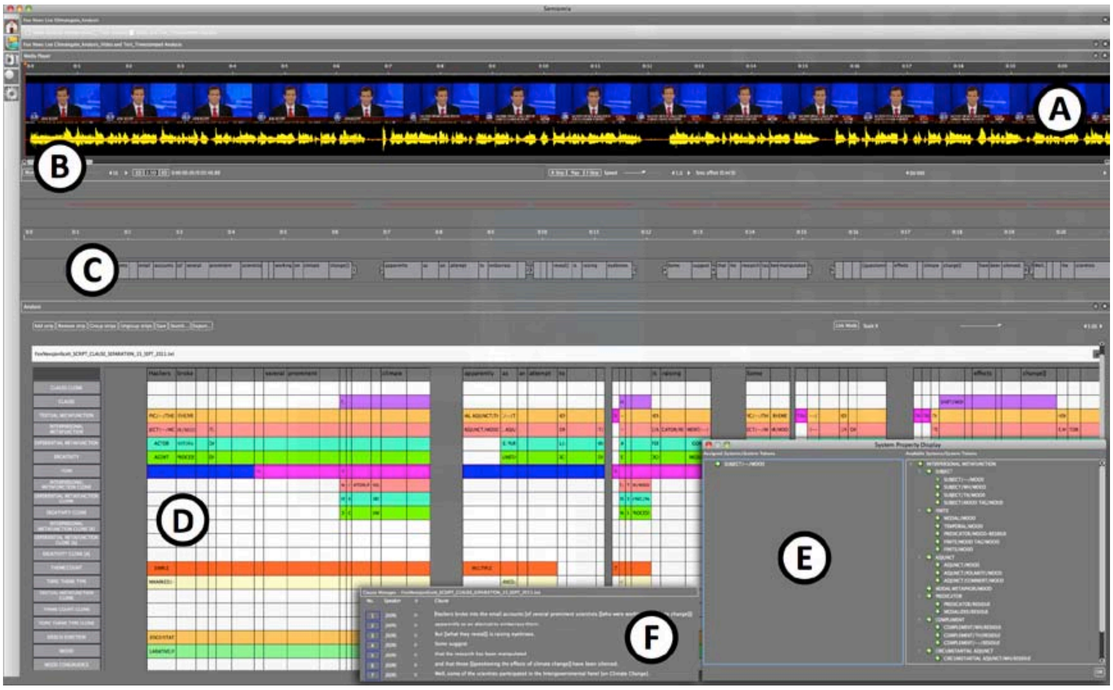


Figure 2(b) Text Time Stamping GUI

(A) Filmstrip and waveform area; (B) Clause overlap navigation area; (C) Time-stamp clause view; (D) Time-stamp clause table view; (E) Systems choice window (F) Clause editor

Figure 2(c) Screenshots of Interviewees with Overlays (Fox News)

(A) Dr Kevin Trenberth (B) Myron Ebell

The annotation units (the nodes and overlays) containing the system choices for linguistic, visual and audio resources are related to each other both in terms of time and space. The ability to precisely encode the spatial-temporal relations between the different choices and store them in a database for later retrieval and analysis is a key step forward for advancing our knowledge and understanding of how choices integrate to create meaning in dynamic media. In addition, facilities are provided for defining and annotating network-like relationships between the annotation units. These relationships are implemented as nested links and chains, which the analyst codes by clicking on an annotation unit and linking it to another annotation unit. The links themselves are annotated using system choices for inter-semiotic relations.

Automated algorithms which are generic enough to enhance productivity are also implemented in the multimodal analysis software: for example, video shot detection for identifying significant changes in the video; audio silence/speech/music classification for identifying intervals of likely silence, speech or music; face detection for identifying faces in videos and images; tracking for automatically tracking objects in videos; and optical flow for detecting the motion of objects, surfaces, and edges.

Search, retrieval and export facilities in the software permit the SFT multimodal base data to be imported into third-party software for mathematical analysis and visualization.

2.3 Mathematical Analysis and Visualization

2.3.1 Techniques for SFT Linguistic Analysis

The aim of the mathematical analysis is to reveal and understand how meaning is being made in texts, in particular the dynamic accumulation of meaning as the text unfolds. The SFT linguistic annotations provide an extensive decomposition of the text into functional elements, typically word groups in clauses which function together as a semantic unit. The meaning potential of these functional elements is multidimensional in the sense that each element plays a role in the different SFT systems. This results in a complex data structure, where the text is decomposed in word groups, which are further grouped into larger and larger groups which are analyzed multiple times according to their metafunctional roles. The data structure includes annotations that are attribute tags attached to each element, or group, where the attribute tags are options drawn from the hierarchically organized SFT systems.

One of the projections of this data structure we have extensively explored is clause-tag associations, which can be conveniently represented as a binary matrix. In this matrix representation each row is associated with a clause, each column is associated with a tag, so tags are attached to the corresponding clause and vice versa. In this data projection the text is represented as a cloud of points in a dual vector space, the clause-space and tag-space, corresponding to the row and column of the binary matrix. The text can be investigated through examination of the dual space, for example, using singular value decomposition (SVD) and clustering techniques. The features of the text are visualized using various network diagrams and by projection of the features back onto the text using color tints and font attributes. The various visual renderings are transformations and filterings of the underlying data structure.

2.3.2 Clustering Techniques for SFT Multimodal Analysis

The complexity of the SFT data structure is increased in multimodal analysis, where time-stamped linguistic annotations and image and video analyses (e.g. camera angle, gaze vectors, on-screen engagement etc) introduce the additional dimension of time. Dimensionality reduction was undertaken using clustering techniques for the k-means algorithm (MacQueen 1967) where k is the number of clusters and binary coding is applied to the annotations. The entire system was divided into different k clusters for the different metafunctions (textual, interpersonal and ideational) and the video analysis, based on iterative techniques to get the best value for k. In addition, network diagrams showed the transitions between clusters for different speakers.

One disadvantage of this approach is that k-means clustering is very sensitive to cluster centers (or choice combinations) so that clauses belonging to the same cluster may not have exactly the same set of annotations. For this reason, the k value must be carefully selected, and in our case, different k values were assigned according to the number of available choices for the different systems for each metafunction.

2.3.3 Allen's Interval Algebra for SFT Multimodal Analysis

To further investigate how different annotations for linguistic, visual and video systems work together to create meaning, patterns of combinations, trends and outliers were analyzed using an algorithmic approach based on Allen's (1983) interval algebra [4]. This approach is explained in some detail because it was used to mathematically model semantic choices as they interact over time.

For the SFT multimodal data, let *annotation A* be a set of *annotation units u*, $A = \{u_i\}$, $i = 1..N$, where *N* is a number of annotation units in the annotation. In case of video analysis, every annotation unit *u* is a triplet $u = (t_1, t_2, c)$, $t_1 < t_2$, where t_1 is start timestamp, t_2 is end timestamp and *c* is the system choice associated with this annotation unit. In other words, the annotation unit defines an interval on the time axis and the system choice attached to that interval. Further, we assume that all annotation units *u* belong to the same annotation A.

In order to describe recurring sets of annotation units, relate sets of units to each other and identify whether a new set of units forms the same pattern as earlier occurring sets we use a fuzzy adaptation of Allen's (1983) interval algebra proposed in Snoek & Worring (2005). This framework defines eight logical relationships, referred to as *Allen's relationships*, stating that any two given time intervals u_1 and u_2 may be:

1. Not related (N)
2. u_1 precedes u_2 (P)
3. u_1 meets u_2 (M)
4. u_1 overlaps u_2 (O)
5. u_1 starts with u_2 (S)
6. u_1 is during u_2 (D)
7. u_1 finishes with u_2 (F)
8. u_1 equals u_2 (E)
9. Not defined (-)

When the 9th relationship holds, the ordering of u_1 and u_2 must be reversed to identify which relationship from 1 to 8 takes place. Let us denote Allen's relationship for time intervals u_1 and u_2 as $\alpha(u_1, u_2)$. Any set of annotation units $u_1, \ldots, u_K$ defines a square matrix $\mathbf{P}(u_1,...,u_K) = \left(\alpha_{i,j}(u_i, u_j)\right)$, where $i, j = 1..K$. In other words, any pairwise combination of annotation units has a corresponding Allen's relationship, and matrix $\mathbf{P}$ describes how annotation units are related to each other in Allen's sense in the given set of units. Obviously, the main diagonal elements of this matrix are equal to E, since any annotation unit is equal to itself. In order to take system choices of annotation units into account we define a *vector of system choices* $\mathbf{c}(u_1,...,u_K) = \left(c_1,...,c_K\right)$, with elements being system choices from annotation units $u_1, \ldots, u_K$.

We define a *pattern* Π as a pair $\Pi = (\mathbf{P}, \mathbf{c})$, where $\mathbf{P}$ is a matrix of Allen's relationships of size $K \times K$ and $\mathbf{c}$ is a vector of choices of size *K*. The set of annotation units $u_1, \ldots, u_K$ is said to belong to pattern $\Pi = (\mathbf{P}^*, \mathbf{c}^*)$ if $\mathbf{P}(u_1,...,u_K) = \mathbf{P}^*$ and $\mathbf{c}(u_1,...,u_K) = \mathbf{c}^*$. This definition naturally demands the annotation units to be in the same configuration in Allen's sense and have the same system choices. The proposed definition of the pattern enables us to move from operating with timestamps to operating with Allen's relationships, providing a mathematical basis to process and compare sets of annotation units in a semantically meaningful domain.

The *pattern histogram*, which is basically counting of patterns of size *K*, is the most basic technique used for this method. The algorithm is outlined as follows:

For all possible combinations of annotation units by *K*.

1. Calculate pattern Π for a combination $u_1, \ldots, u_K$.
2. Assign counter 1 for Π in case it never occurred before or increment the counter otherwise.

The pattern histogram is used to identify the most frequent patterns in the SFT multimodal base data. The main disadvantages of this approach are the large number of patterns discovered and the necessity to explicitly define parameter *K*, the size of the patterns to look for. Even a simple analysis may generate thousands of unique combinations, and this number grows exponentially with increase of *K*. Therefore, we propose a basic filtering technique for pattern histogram calculation, which filters out all patterns having (N), *i.e.* the 1st Allen's relationship. This approach is motivated by the idea that if two annotation units are 'not related' in time, than it does not make sense to consider these units in the pattern. This technique filters the vast majority of the patterns, but the total number is still too high to be interpreted by the human analyst.

The large number of unique patterns is generated because the algorithm takes all possible combinations of annotation units into account. Therefore, even a small number of annotation units may generate much higher number of patterns since pattern histogram does not favor any pattern, accounting for them all. Further filtering of pattern histogram can be done based on the assumption that one may be interested in more repeated patterns than in less repeated ones. We may, therefore, require that patterns with a lower counter may not share annotation units with higher counter patterns, that is, annotation units that contribute to a pattern with a higher counter may not contribute to a less frequent pattern. The algorithm may be outlined as follows:

1. Calculate pattern histogram.
2. Sort patterns in histogram by their counter.
3. Starting from pattern Π with higher counter.
4. Check if there are patterns with lower counter sharing annotation units with Π.
5. Reduce their counters accordingly.
6. Delete pattern Π if its counter reaches 0.
7. Repeat for all patterns.

This approach favors highly repeated patterns to less frequent patterns and greatly reduces the total number of patterns in the histogram making it easier to interpret manually. The approach still requires the pattern size K to be explicitly defined, however. This is problematic since it is difficult to estimate K in advance and the different patterns in the SFT multimodal data may have different sizes. To address these problems, an alternative approach was developed.

Consider a pattern Π of size $K>2$ repeated n times, and let us investigate the results for patterns of size K-1 in the same SFT multimodal base data. Naturally, sub-patterns of Π will be discovered and these sub-patterns will have the counter bigger or equal *n*. In any annotation, smaller size patterns contributing to a bigger size pattern are present as frequently or more frequently than the bigger pattern itself. In this sense, we can identify larger size patterns by analyzing their smaller size components. In fact, we can calculate pattern histogram for K=2 and then analyze it to identify patterns of any size by looking at how patterns share annotation units. Sub-patterns of a bigger pattern use the same annotation units or, more precisely, their sets of annotation units intersect to a great extent. Checking all patterns pairwise can identify this intersection by detecting the annotation units, which belong to both.

This approach converts the pattern histogram into a network, where the nodes of the network are patterns, and edges between two patterns are recorded when sharing of annotation units is detected. Patterns of bigger size form clusters of densely interconnected clusters of nodes in the network, which can be later detected by parsing the network structure. This approach combined with a mutual exclusiveness requirement for a histogram makes identification of bigger size patterns practically possible since it avoids exponential complexity explosion by looking at patterns of size K=2 only.

These mathematical techniques were applied to SFT linguistic base data and SFT multimodal base data derived from the following case studies.

2.4 The Case Studies

2.4.1 Global Financial Crisis and Climate Change

Six case studies selected for analysis in the first phase of the project. Case Study 1 is concerned with a financial advisor's view of the global financial crisis which unfolded in 2008, while Case Studies 2 to 6 are selected from a corpus of texts on climate change, in particular those focusing on events surrounding the United Nations Copenhagen Climate Change Summit 2009 (COP15) in Copenhagen, Denmark on 7-18 December 2009. The financial crisis and climate change were chosen on the basis of their global significance and the evolution of media reporting about these two events. The reporting of the financial crisis has a shorter time span compared to climate change which has been the subject of discussion for decades. Both issues are currently being reported, however, within an environment where there is a basic distrust of the different interest groups and mainstream institutions (e.g. banks).

The six case studies are:

1. Title: ‘Commentary: Why there is a crisis – and how to stop it’
   Author: David Smick
   Source: *CNN News*
   http://edition.cnn.com/2008/POLITICS/10/09/smick.crisis/index.html
   Date: 10 October 2008
   Type: Website
   Description: A financial advisor presents his views regarding the origins of the global financial crisis and what needs to be done in order to restore the situation.

2. Title: ‘Are climate scientists over-selling their models?’
   Author: Fred Pearce
   Source: *New Scientist*
   http://www.newscientist.com/article/mg20026851.900-are-climate-scientists-o versellling-their-models.html?full=true
   Date: 4 December 2009
   Type: Website
   Description: Professor Lenny Smith, a climate scientist at the London School of Economics, is interviewed regarding the usefulness of climate models for forecasting climate and weather patterns.

3. Title: ‘Hackers target leading climate research unit’
   Author: BBC News Online
   Source: *BBC News*
   http://news.bbc.co.uk/2/hi/8370282.stm
   Date: 20 November 2009
   Type: Website
   Description: The text is a news report on the email hacking incident that occurred at the Climatic Research Unit at the University of East Anglia in November 2009, just before the United Nations conference on climate change (COP15) in

Copenhagen.

4. Title: ‘Hackers steal electronic data from top climate research center’
Author: Juliet Eilperin
Source: *The Washington Post*
http://www.washingtonpost.com/wp-dyn/content/article/2009/11/20/AR2009112004093.html
Date: 21 November 2009
Type: Website
Description: The text also reports on the email hacking incident that occurred at the Climatic Research Unit at the University of East Anglia.

5. Title: ‘Q&A: Professor Phil Jones’
Author: Roger Harrabin
Source: *BBC News*
http://news.bbc.co.uk/2/hi/8511670.stm
Date: 13 February 2010
Type: Website
Description: Roger Harrabin, one of the world’s most senior environment and science journalists, interviews Professor Phil Jones, who was head of the Climatic Research Unit at the University of East Anglia in Britain when the email hacking incident occurred.

6. Title: ‘Phil Jones momentous Q&A with BBC reopens the “science is settled” issues’
Author: Indur M. Goklany
Source: *Watts Up with That*
http://wattsupwiththat.com/2010/02/14/phil-jones-momentous-qa-with-bbc-reopens-the-science-is-settled-issues/
Date: 14 February 2010
Type: Website
Description: The text is a blog entry from the well-known climate change blog *Watts Up with That*, managed by Anthony Watts, an American broadcast meteorologist. The text was written by a guest writer, Indur M. Goklany.

The six texts were selected on the basis of their relations with each other. That is, Case Studies 1 and 2 were chosen to see how experts from two different domains, one of science and another of economics and finance, make use of linguistic choices to achieve their communicative intent. Case Studies 3 and 4 were selected to investigate how texts from different news agencies reported on the same event, and Case Studies 5 and 6 provided insights into the framing of expert opinions about an event. The analysis of the six case studies reveals significant differences in how the resources of language are employed to communicate information and influence readers.

2.4.2 Climate Change and Email Hacking Incident: Written Reports

The *BBC News* and *Washington Post* texts (Case Studies 3 and 4) about the email hacking incident at the Climatic Research Unit at the University of East Anglia in November 2009 were revisited in phase two of the project to further examine the usefulness of the visualization facilities in Systemics and to assist in the development of mathematical tools for tracking the dynamics of the text. The two texts are initial reports of the ‘Climategate’ incident, which happened about two weeks before the United Nations Conference on Climate Change in Copenhagen in December 2009. The *BBC News* and the *Washington Post* texts were chosen to investigate ideological differences in the two reports.

2.4.3 Climate Change and Email Hacking Incident: Televised Interviews

The focus turned towards televised interviews about the email hacking incident at the Climatic Research Unit at the University of East Anglia in the third phase of the project. Two videos from *Fox News* (http://www.foxnews.com/) and *CNN News* (http://edition.cnn.com) were analyzed in terms of linguistic, image and video systems for textual, interpersonal and experiential meanings for the purpose of examining the interactional and experiential content of the video and the degree of persuasiveness with which each interviewee puts forth his case. The details of these two videos are given below.

1. Program: *Happening Now*, a Fox News Corporation breaking-news programme

Date: 25 November 2009

http://video.foxnews.com/v/3945521/illegal-act

Interviewer: Jon Scott

Interviewees:

- Dr. Kevin E. Trenberth: Distinguished Senior Scientist in the Climate Analysis Section at the National Center for Atmospheric Research in Colorado
- Mr. Myron Ebell (Director of energy and global warming policy at the Competitive Enterprise Institute, Washington DC).

2. Program: *Campbell Brown*, a former CNN news program

   Interviewer: Campbell Brown

   Date: 7 December 2009

   http://www.youtube.com/watch?v=Tsh7QUy4CvE

   http://www.youtube.com/watch?v=ucz_iCJCoZE&feature=watch_response_rev

   Interviewees:

- Chris Horner: Senior Fellow, Center for Energy and Environment the Competitive Enterprise Institute in Washington DC
- Stephen McIntyre: Mathematician and founder and editor of *Climate Audit*, a blog devoted to the analysis and discussion of climate data
- Michael Oppenheimer: Albert G. Milbank Professor of Geosciences and International Affairs in the Woodrow Wilson School and the Department of Geosciences at Princeton University and Director of the Program in Science, Technology and Environmental Policy (STEP) at the Woodrow Wilson School and Faculty Associate of the Atmospheric and Ocean Sciences Program, Princeton Environmental Institute, and the Princeton Institute for International and Regional Studies.

3 Results and Discussion

3.1 Semantic Patterns and Comparative Analysis

One of the key innovations of the project is that many of the qualitative aspects of meaning making in a text previously described by Halliday (1978), Halliday and, Matthiessen (2004), Martin (1992) and others, can be associated with quantifiable aspects of our data structures [3], [4], [5], [6], [7]. For example, qualitative features can be identified with reference points in the clause-tag dual-space. The degree to which a text possesses a feature can be described in terms of barycentric coordinates with respect to predefined reference points and metrics. The findings for the six case studies are described below.

In the *CNN News* text (Case Study 1), the financial advisor presents his views regarding the origins of the global financial crisis and what needs to be done in order to restore the situation. The analysis reveals that although on the surface the text appears to present an objective view of the financial crisis, there are multiple underlying strategies where the author uses a range of linguistic systems (particularly modality and transitivity systems) in a metaphorical fashion to present himself an authority with knowledge of both the causes and solutions to the global financial crisis. This may be compared to the *New Scientist* text (Case Study 2), where the scientist constantly qualifies his statements about the usefulness of climate models through the use of congruent modality resources (e.g. Finite elements, Mood Adjuncts), unlike the global financial advisor in Case Study 1 who uses metaphorical resources to achieve a high level of apparent certainty.

The visualization techniques revealed semantic patterns in these texts which otherwise would have been difficult to detect. For example, in the *CNN News* text (Case Study 1), recurrence plots revealed phases in transitivity patterns in descriptions of the global financial crisis corresponding to the author's recount of events (in terms of material actions) and his solution to the problem (in terms of relations between different entities) as displayed in Figure 3. Significantly, the semantic patterns involve interactions across different grammatical systems. For example, recurrence plots were used to identify relations across system choices for textual organization and logical meaning in Figure 4 and transitivity and lexical strings which function to amplify the magnitude of the final crisis in Figure 5. The analyses reveal the inter-dependency of semantic systems and illustrate the need to adopt a multi-layered and multi-faceted analysis of text [6], [7].

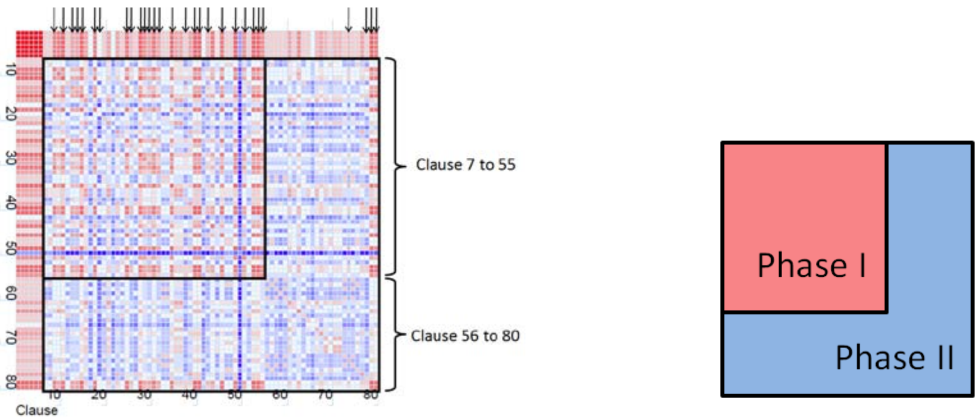
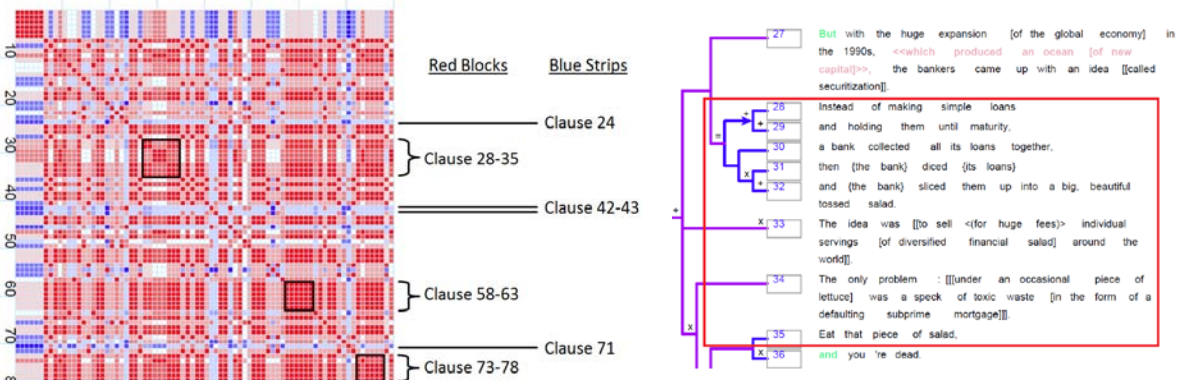


Figure 3 Transitivity Phases



“Red Block 1”: Clauses 28-35

Figure 4 Thematic Patterns and Logical Meaning

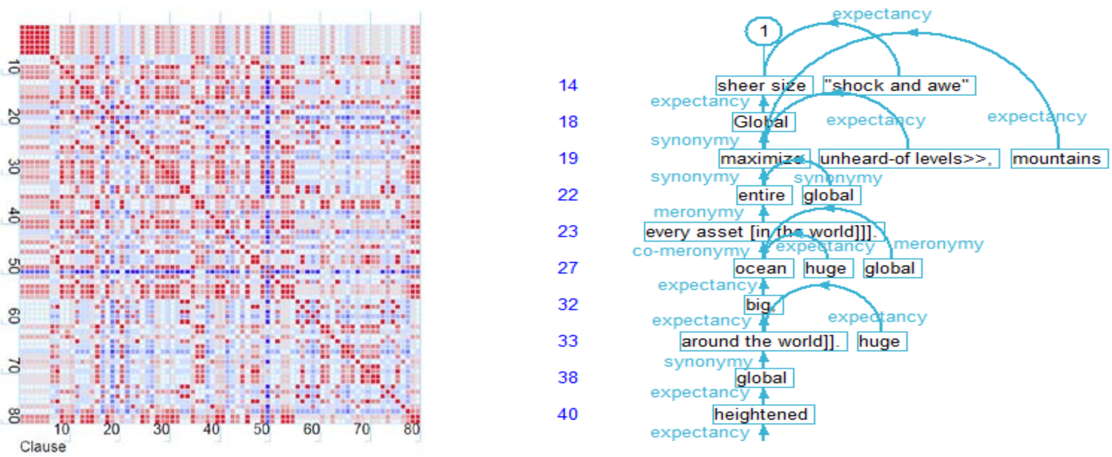


Figure 5 Transitivity and Lexis: Amplification of Financial Crisis

The *BBC News* text (Case Study 3) was one of the first news reports about the email hacking incident at the Climatic Research Unit at the University of East Anglia to emerge. The analysis reveals that the text producers reconstruct the event in terms of a theft of information (i.e. a burglary), which functions to subordinate the controversy regarding claims of data manipulation. The focus of the article is directed towards security measures at the university, rather than the researchers working in the Climatic Research Unit. The SVD illustrated key semantic features of texts [1], [7]; for example, the use of modality (i.e. truth value) and co-occurrence of semantic tags (Finite Modal and 'TH' Subject) as displayed in Figure 6.

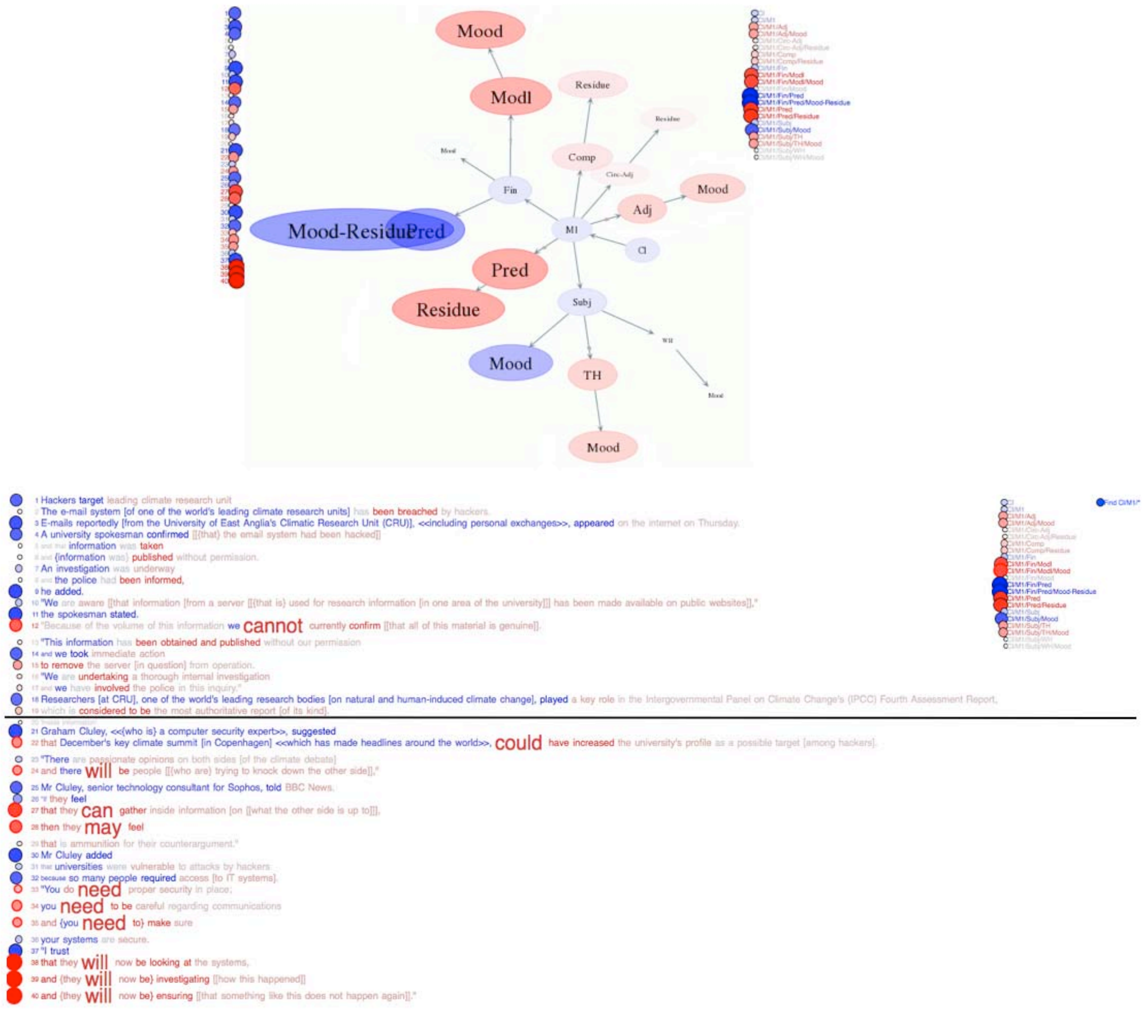


Figure 6 Tag Wheel and Text Visualization

On the other hand, the *Washington Post* (Case Study 4) focuses on the controversy arising from the email hacking event and positions climate change proponents and climate change skeptics as opposing parties, with the proponents being presented as defensive and the skeptics as objective and confident in their claims. Later, the *BBC News* (Case Study 5) Professor Jones is questioned on several points arising as a result of this controversy – including the use of the word ‘trick’ and the accusations that the science behind global warming is not as strong as climate scientists have argued it to be. The analysis reveals how the scientist tends to use relational processes to describe particular states, without drawing upon interpersonal resources to make explicit evaluations of those states, unlike the *Watts Up with That* text (Case Study 6) where modality is frequently used. The findings suggest that climate change proponents and climate change denialists may rely on different meaning-making strategies, particularly in relation to the expression of uncertainty and doubt. Interactive visualization tools permitted comparison of such semantic patterns across the six case studies, as displayed in Figure 7.

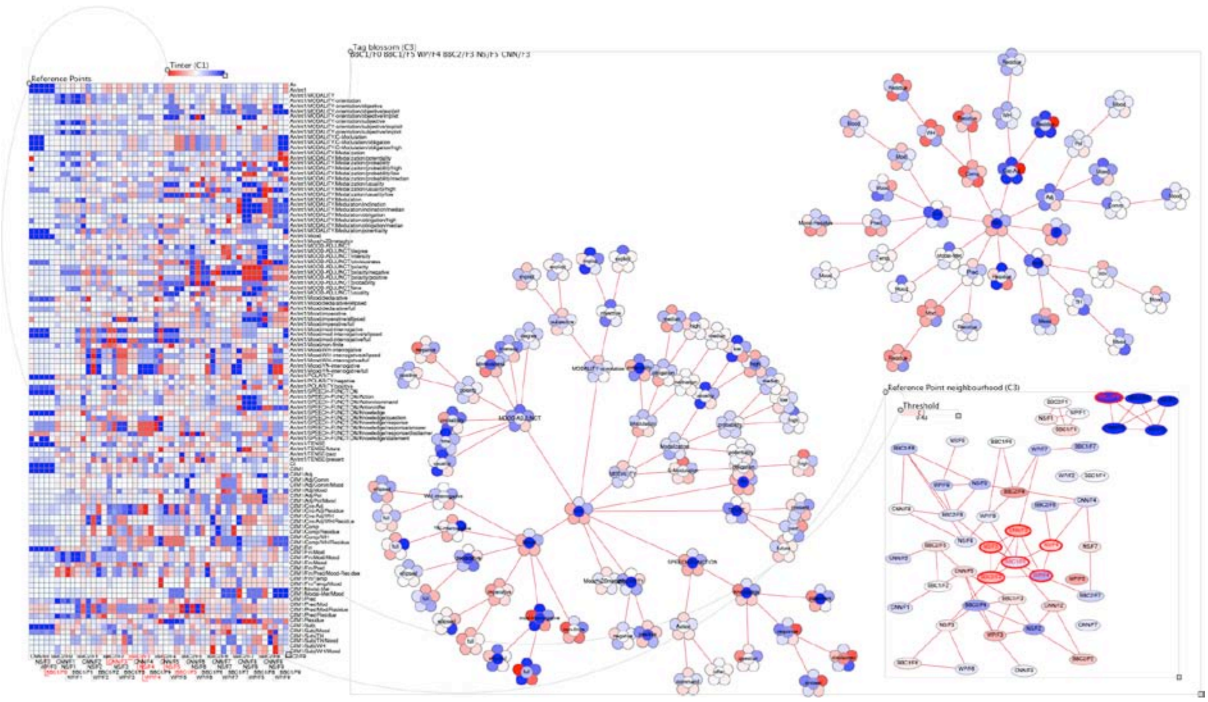


Figure 7 Interactive Visualization Comparing the Features of Six Texts

While qualitative aspects of meaning making in a text are associated with quantifiable aspects of data structures, making possible the visualization of semantic patterns, modeling the dynamics of the unfolding meaning in a text proved more challenging. Different approaches were explored, for example, the accumulation of semantic features over the logical structure of the text in Figure 8, state machines derived from projection and clustering of the underlying data structure in Figure 9 and animations of unfolding features within a text in Figure 10.

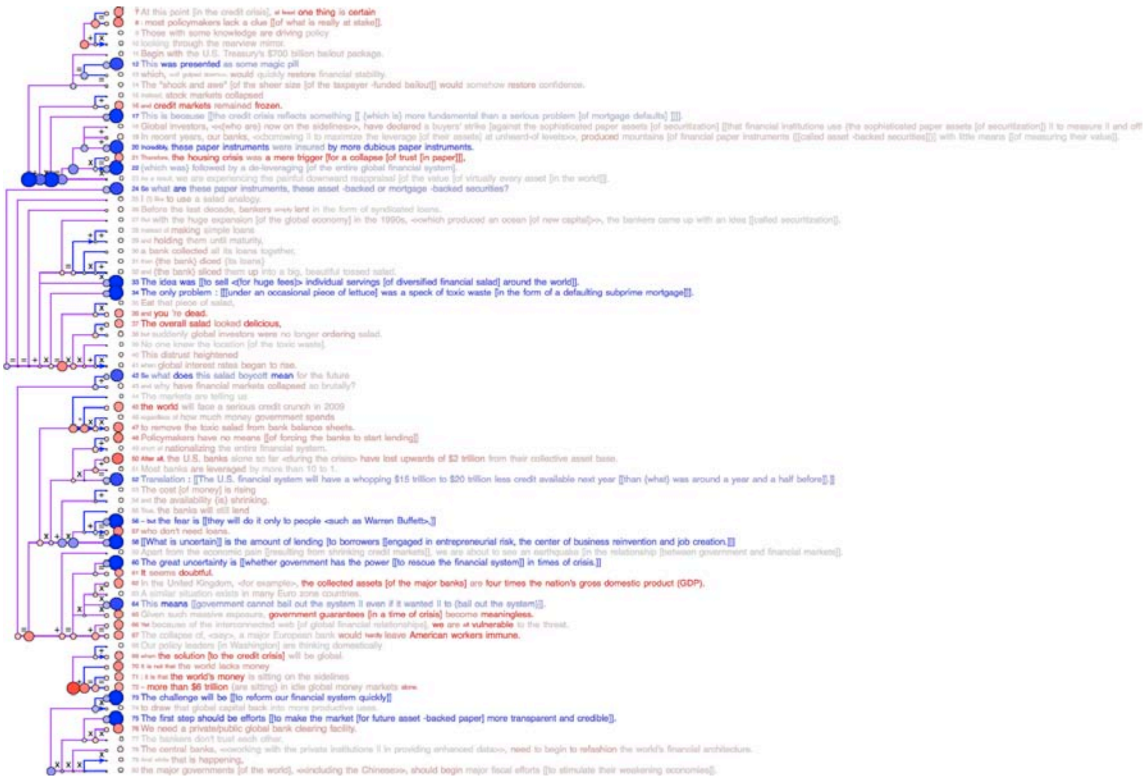


Figure 8 Accumulation of Features over Logical Structure

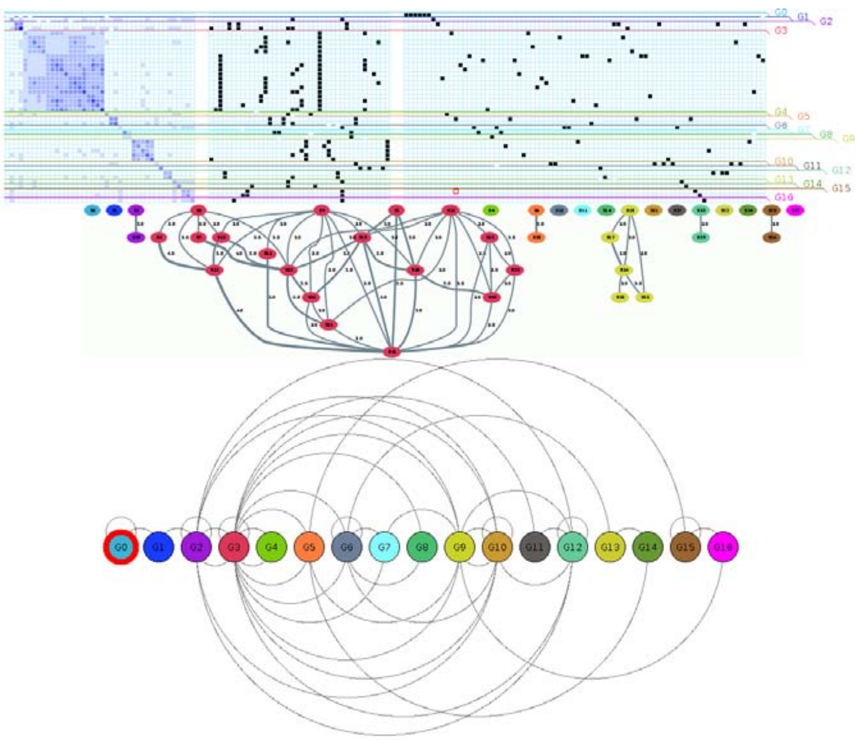


Figure 9 State Machine Based on Clustering in Dual-Space

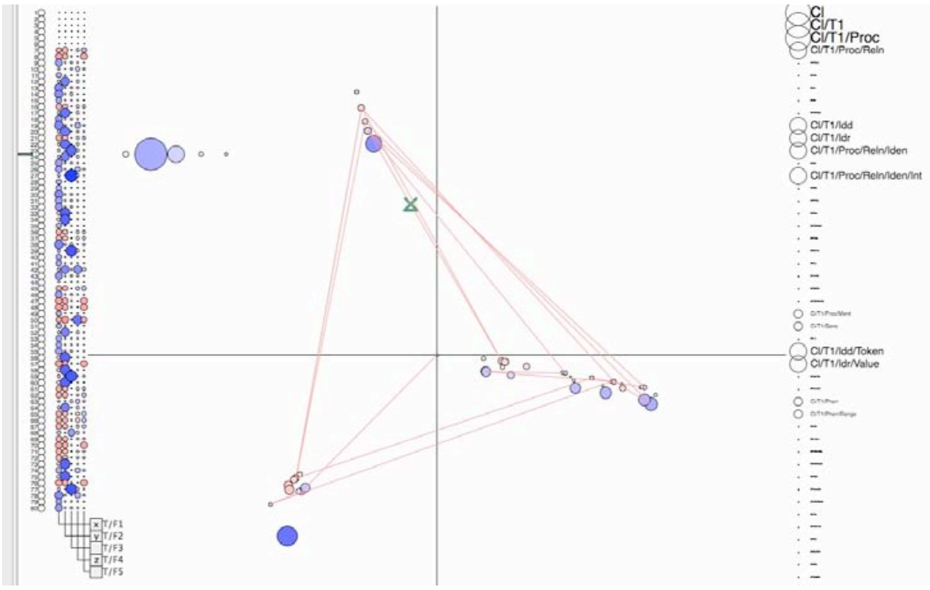


Figure 10 Unfolding Features in a Text

3.2 Generic Profiles for Written Texts

One of the key advantages of our quantitative description of meaning making in texts is that it enables comparative analysis of texts, and the identification of features of a text that deviate from genre norms, thus making it possible to interpret covert messages (experiential, logical, interpersonal and textual) which are not immediately apparent. For example, a comparison of mathematical visualizations (i.e. neighborhood plots, recurrence plots, tag wheels) for the *BBC News* (Case Study 3) and *Washington Post* texts (Case Study 4) about the email hacking incident at the University of East Anglia reveal different linguistic properties and construals of the event, as explained below.

The *BBC News* and the *Washington Post* texts are essentially news recounts of the same event. Both texts contain a third-person recount of the event, following which certain individuals are called upon to give their thoughts and opinions with regard to the event. However, even with a similar communicative purpose, the two texts differ in the construal of the event. The *BBC News* text has a narrower focus and contains a smaller variety of lexical verbs, focusing mainly on the statements made by the affected university, the police and the IT expert. In contrast, the *Washington Post* text expands the semantic field to include verbs which ‘do’ more than just make statements, such that the resultant effect is a degree of ‘action’ which exceeds the generic expectation of a recount as the re-telling of facts. Simply put, there is a lot less ‘action’ in the *BBC News* text compared to the ‘drama’ construed in the *Washington Post* text. Aided by particular tense and modality values assigned to participants in the text (in particular, those who were invited to give their views on the incident), the ‘who’ and their respective actions take centre stage in the *Washington Post*, while the *BBC News* text focuses on the event and ‘what’ happened.

The quantification of semantic features for generating generic text profiles and speaker profiles for email hacking event was explored in relation to SFT multimodal base data for video texts in the final phase of the project.

3.3 Generic Profiles for Video Texts

3.3.1 Cluster Distribution over Time

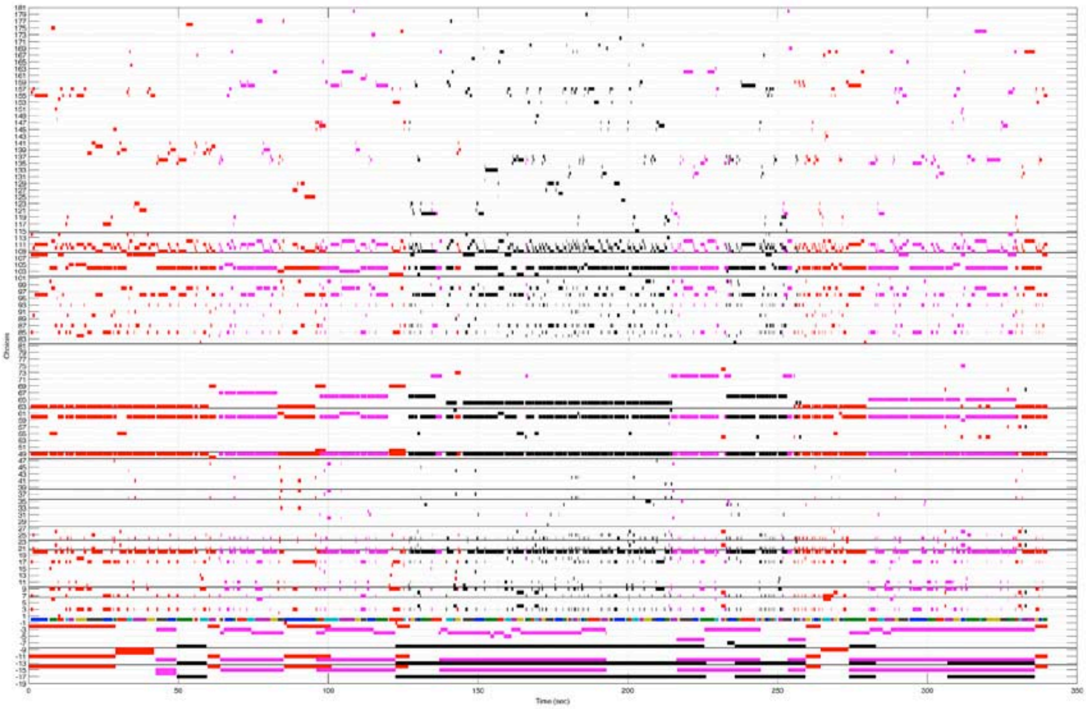


Figure 11 Time-Stamped SFT Multimodal Data Base

The visual complexity of the time-stamped SFT multimodal data for the *Fox News* interview about the email hacking incident at the Climatic Research Unit at the University of East Anglia (155 clauses with 198 different types of linguistic and image/video annotations) is displayed in Figure 11. The colors red, pink and black correspond to linguistic, visual and video choices for Jon Scott, the interviewer (Speaker 1), Dr Kevin Trenberth, the climate scientist (Speaker 2) and Mr Myron Ebell, the climate denialist (Speaker 3) respectively.

Mathematical techniques were applied to the multimodal SFT base data to interpret the news debate genre where a seemingly unstructured conversational context is actually governed by codes of behavior regarding the conduct of the communicative event and the nature of the participant roles. From clustering and network visualizations, we investigated some of these norms; for example, how limited speaking time for participants leads to competition for control of the dialogic space, especially in a debate where participants, in this case Dr Trenberth and Mr Ebell, address certain issues from opposing points of view.

The k values for the k-means clustering for the system annotations were assigned according to metafunction (textual, interpersonal, ideational) and resource type (language and image/video). The resulting k value are: Textual: 8 (155*20 matrix with 633 non-zero elements); Interpersonal: 12 (155*81 matrix with 1333 non-zero elements); Ideational: 12 (155*79 matrix with 954 non-zero elements) and image/video: 8. Figure 12 shows the cluster distribution over time for Jon Scott, Dr Trenberth and Mr Ebell (red, pink and black respectively), where clusters from 1 to 8 belong to Textual system, clusters 9 to 20 belong to Interpersonal system, Clusters 21 to 32 belong to Ideational system for language and -8 to -1 belong to video. The dimensionality of the data matrix has been reduced from 155*198 to 155*40.

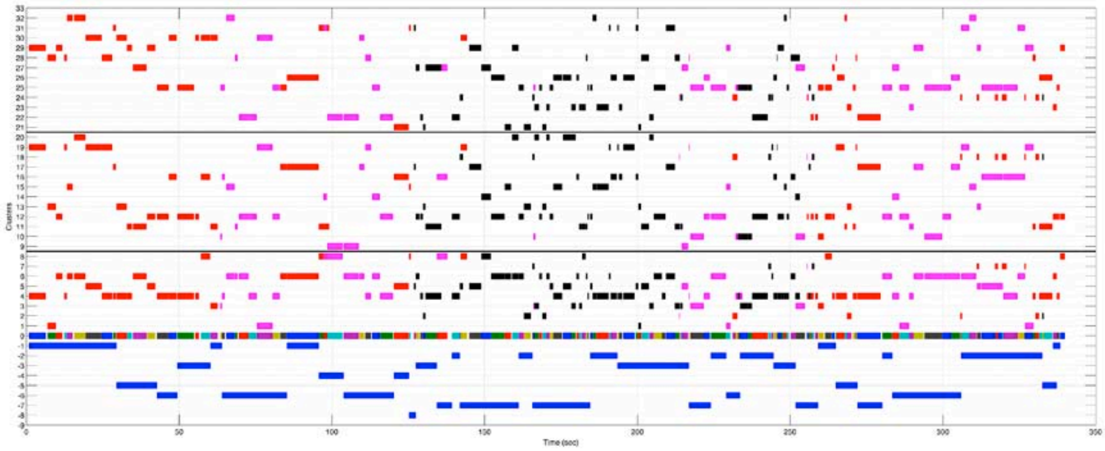


Figure 12 The Distribution of the Clusters over Time

The most repeated cluster combinations-of-three were analysed to find semantic patterns in the discourse and the most significant combinations for the three speakers. Figure 13 shows the occurrence of most repeated cluster combinations-of-three, where three distinct episodes were identified. The first episode contains a variety of clusters, while the second episode has more variation within a tighter time frame. The third episode, while somewhat similar in terms of length of time frame as the second episode, contains a distinctly different set of cluster combinations-of-three. These three episodes are examined in more detail below.

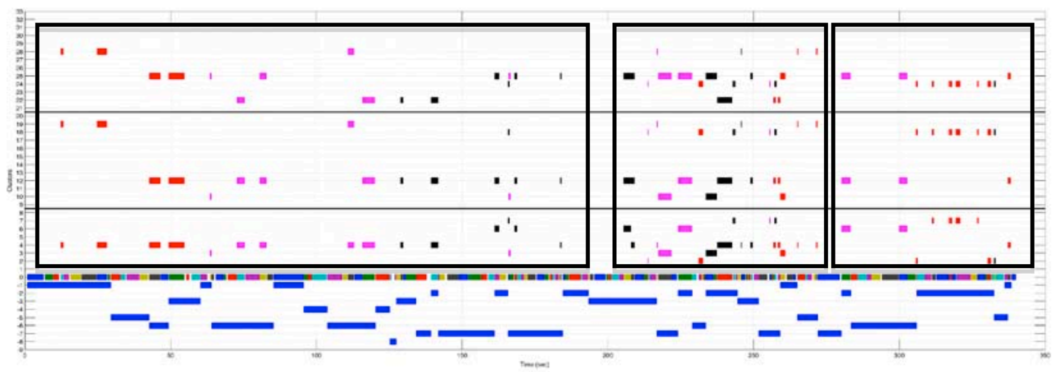


Figure 13 Most frequent cluster combinations-of-three

Visually, the flow of contributions from Jon Scott, Dr Trenberth and Mr Ebell (coloured red, pink and black respectively) in the first episode develops into a somewhat frenzied ‘exchange’ with more frequent short bursts amidst the increased variation in cluster combination-of-three in the second episode, following which there is a recapitulation of sorts in the third episode, but it is not a repetition of the first episode. Mr Ebell is much less prominent in the last episode, in contrast to the middle episode where he seems to dominate the discourse, particularly in comparison to the first and last episodes.

The repeated combination reveal discourse patterns which are indicative of an interesting phenomenon. Using Jon Scott as an example, we see a marked difference in cluster combination-of-three use between the first episode and the third. If we refer back to the *Fox News* interview, we see that Jon Scott, as interviewer, is trying to bring the news debate interview to a close in the third episode by acknowledging his guests. However, Dr Trenberth interjects with new information and Jon Scott only gets as far as uttering his guests' names before he is interrupted. Thus, there is a repetition of cluster combination-of-three which are 'nil choices' as the clauses labeled with this combination-of-three are 'Minor Clauses' which do not have tag annotations in either of the three metafunctions because they do not carry textual, interpersonal or experiential meaning.

However, in the first episode, Jon Scott is engaged in a question-answer type interaction where he and Dr Trenberth are not competing for speaking time, but rather questions are asked and responses are made. In fact, both speakers share similarities in cluster combination-of-three use in the first episode, and this could perhaps be indicative of a less tense part of the news debate interview, compared to the second episode where Dr Trenberth attempts to address Mr Ebell's arguments against him and his science colleagues.

Thus from the cluster visualizations, we can observe patterns in the dynamics of the text that can be verified and investigated further upon reference back to the actual text itself. The interview is clearly divided into three distinct parts, with a middle part that is quite different from the rest. An examination of cluster occurrence within each episode has also shown characteristics that are unique, and provide tangible preliminary evidence for the sequential development of any text in stages which are particular to that register and genre.

3.3.2 Network visualizations

Network visualizations also reveal significant patterns in the text, for example, when a speaker is continuously prevented from finishing his utterances, or if a speaker uses particular clusters repeatedly or in sequence. Figure 14(a)-(c), for example, displays a concentration of clusters and cluster relationships that are characteristic of Jon Scott, Dr Trenberth and Mr Ebell with regards to their manner of organizing their discourse, while also showing which clusters are outliers in this particular network pattern. These patterns reveal the differences between the three speakers, as described below.

Interviewer Jon Scott favours simple forms of textual organization (Cluster 4 in Figure 14(a)) which enables him to quickly focus on issues of concern, while Dr Trenberth frequently uses conjunctions like ‘and’ and ‘but’ to elaborate and explain on the points he is trying to make (Cluster 6 in Figure 14(b)). Mr Ebell uses a wide range of textual resources, including conversational continuatives which result in many cluster pairings (e.g. Cluster 3-6, Cluster 4-6 and Cluster 4-5 in Figure 14(c)) and repetition of simple forms of thematic organization (Cluster 4 in Figure 14(c)). Mr Ebell’s use of simplified forms of repetition have the effect of reinforcing his arguments which are delivered in a conversational style, compared to Dr Trenberth’s uneven attempts to logically connect the events which are under discussion during the interview.

Such patterns, besides giving an indication of speaker profile, can also contribute towards the profiling texts genres because such semantic patterns are indicative of patterns at a register level (e.g. use of interrogatives, and interpersonal vocative themes in news debate interview contexts).

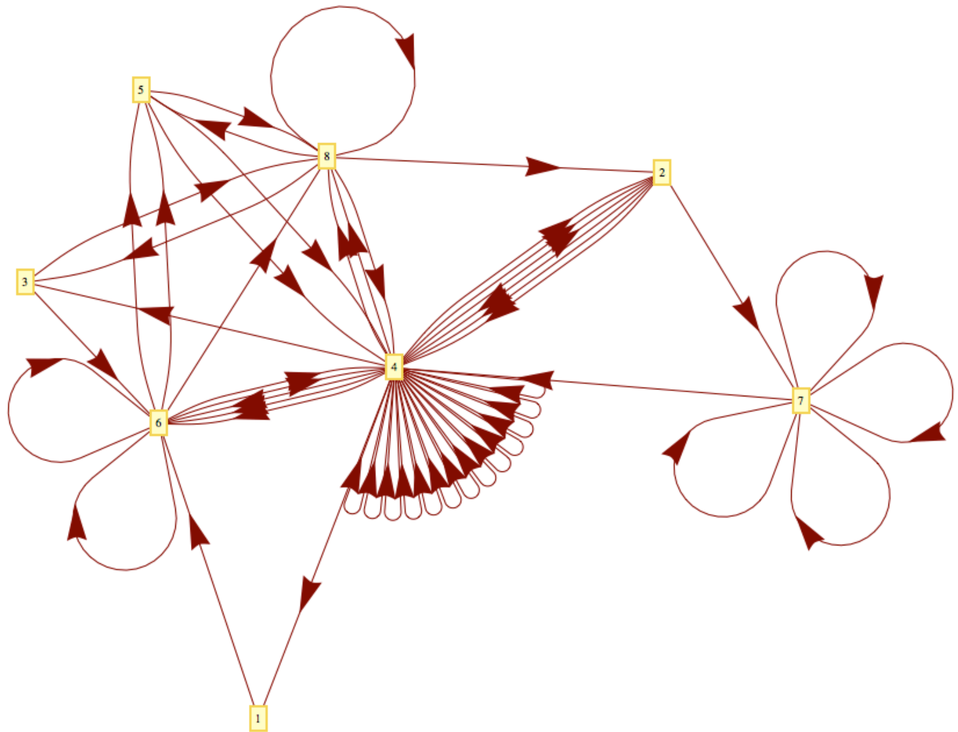


Figure 14(a) Textual Metafunction: Jon Scott

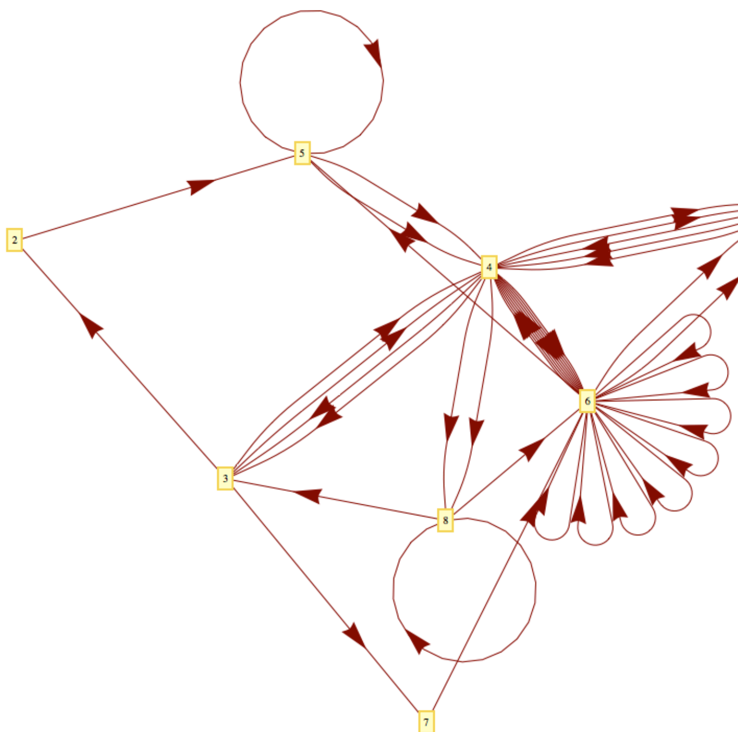


Figure 14(b) Textual Metafunction: Dr Kevin Trenberth

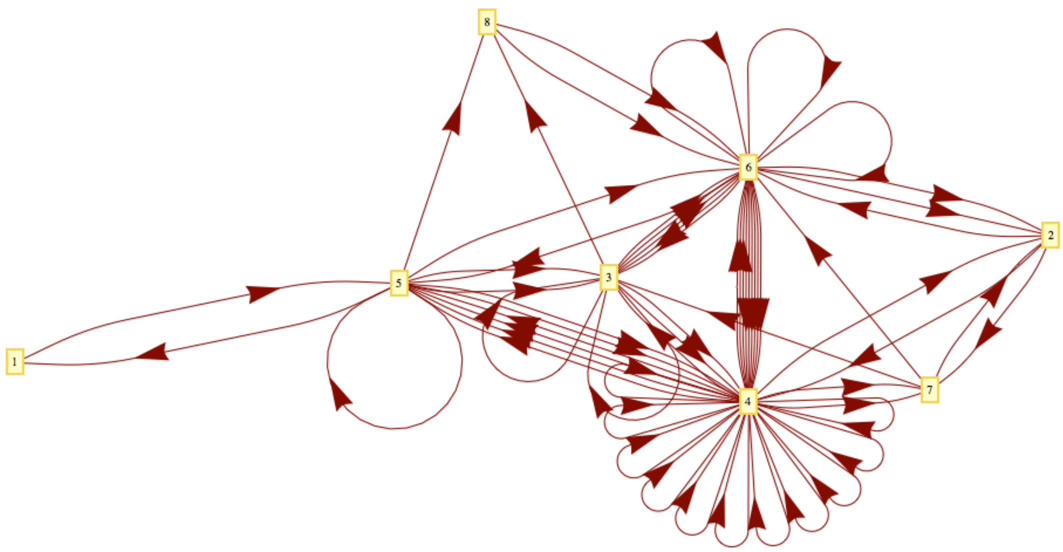


Figure 14(c) Textual Metafunction: Mr Myron Ebell

The combination of time-based visualization and network visualization moves beyond more obvious measures like total duration of speaking time to look at what actually happens during the exchange. For example, Mr Ebell speaks for the shortest time compared to the other two speakers, but emerges as the more dominant because of his choices during an extended period of speaking time, as further discussed below.

3.4 Generic Speaker Profiles

The k-means clustering and network visualizations show different patterns for the three speakers in terms of type, directionality and frequency. These differences can be seen as unique to each speaker, and upon reference back to the text, show differences in semantic meaning and stylistic preferences. The analysis undertaken using Allen's temporal logic contributes further information about the speaker profiles, in this case for Mr Ebell, the lobbyist at the Competitive Enterprise Institute and a well-known climate denialist, and Dr Trenberth, an international recognized climate scientist who was recipient of some the hacked emails though not directly incriminated by them. As we shall see, the different agendas of the two speakers are played out in the televised interview [5].

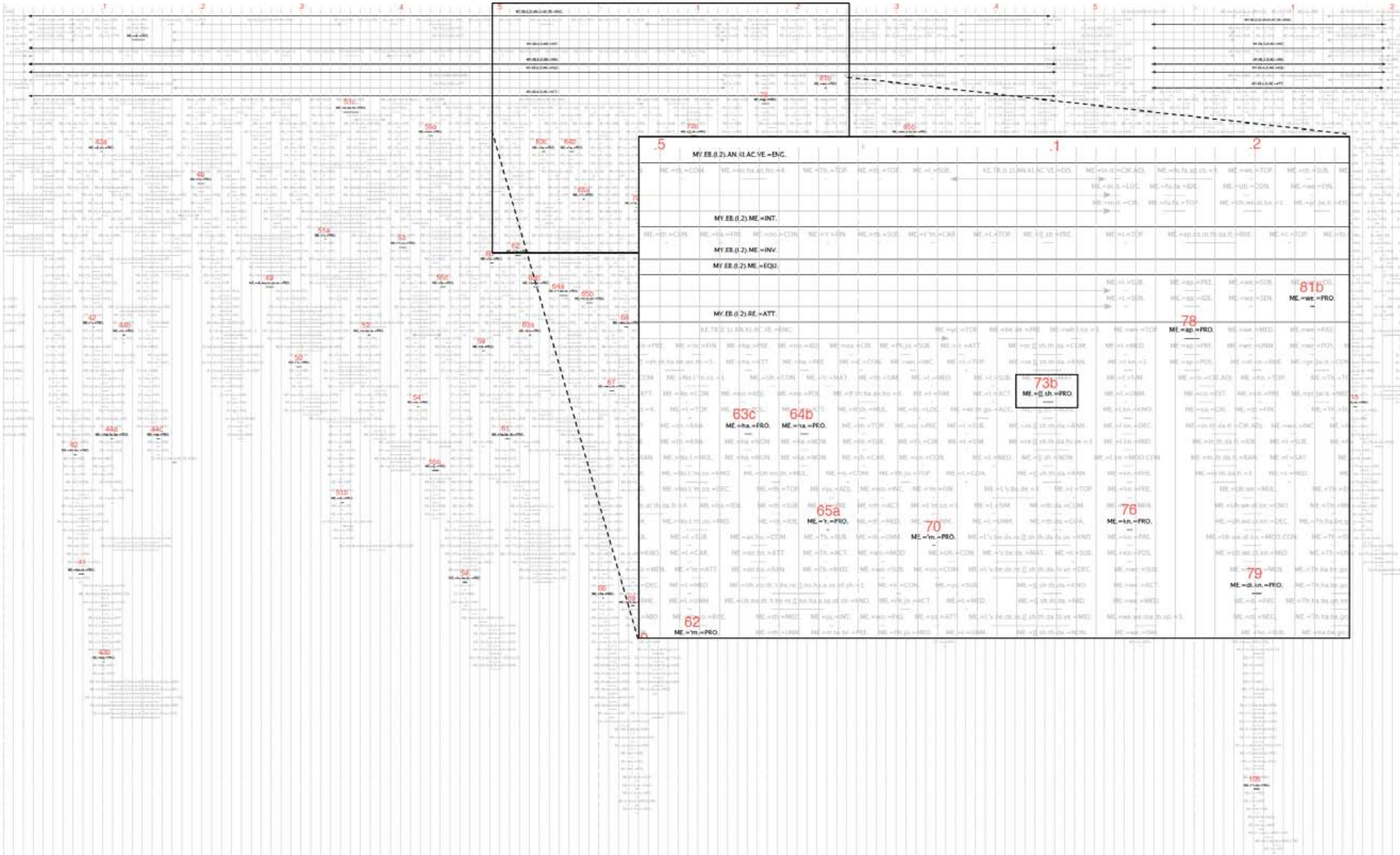


Figure 15(a) (Partial) Strip data for Mr Myron Ebell

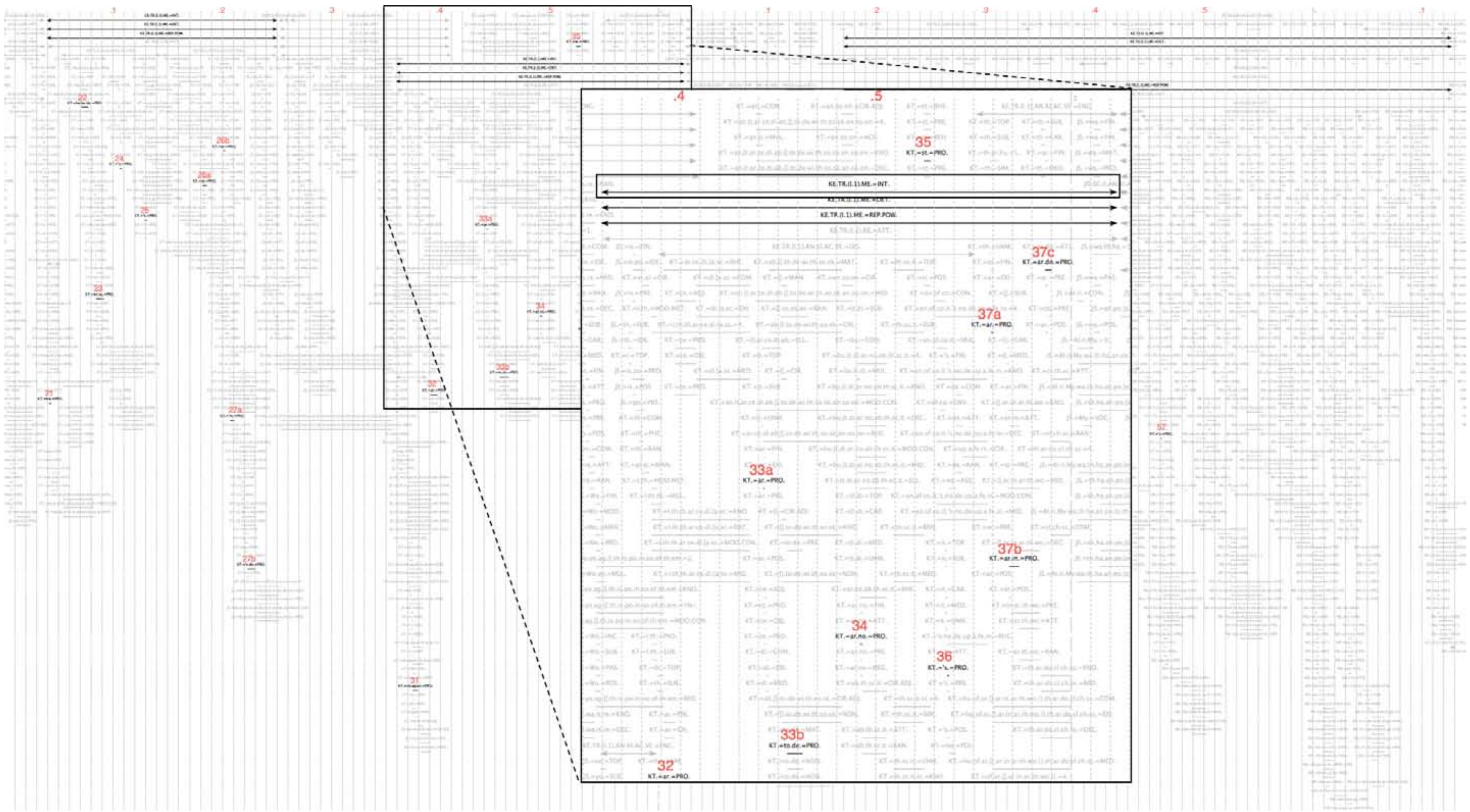


Figure 15(b) (Partial) Strip data for Dr Kevin Trenberth

Figure 16(a) Regions of occurrence of identified pattern for Mr Myron Ebell

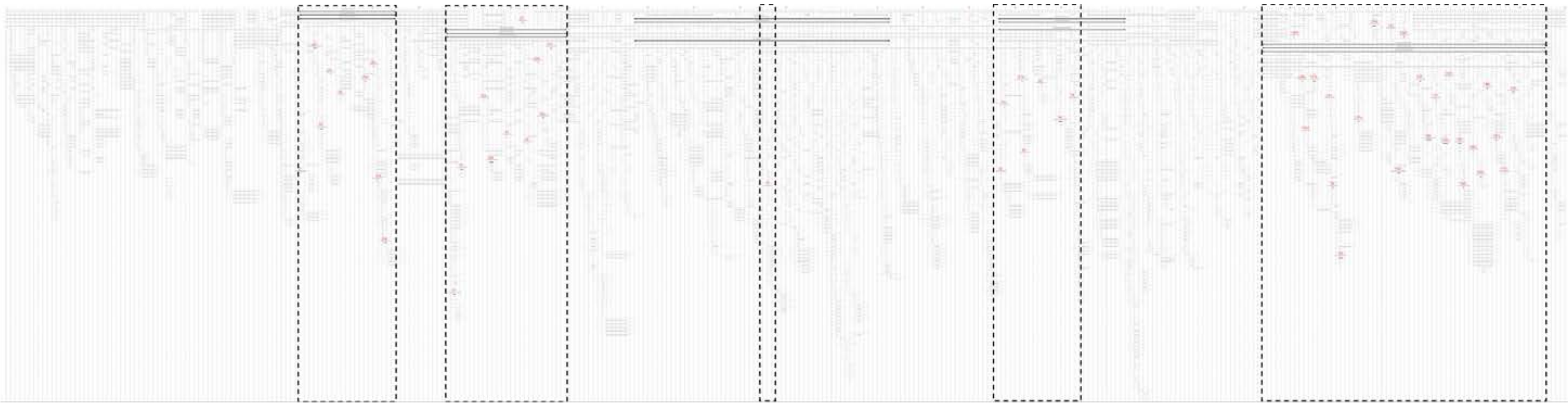


Figure 16(b) Regions of occurrence for identified pattern for Dr Kevin Trenberth

Figures 15(a)-(b)[1] display segments from two strips of SFT multimodal base data, with an insert showing an enlarged portion of the strip. The first strip is derived from SFT multimodal data for Mr Ebell, and the second, from SFT multimodal data for Dr Trenberth. The strips are made up of 'units'[2] (highlighted in black boxes in Figures 15 (a)-(b)), where units consist of an annotation with start and end times. In each strip, the bold units belong to networks of patterns or 'clusters' selected on the basis of frequency and strength.

The choices in the units for the patterns are 'Interactive Meaning' in the video analysis and 'Process' in the linguistic analysis. These are key system choices in the inter-semiotic discoursal structure for visual images and language. The larger pattern count of 73 for Mr Ebell versus 52 for Dr Trenberth over two regions in the discourse (particularly in the long middle segment of the video), as compared to the smaller discourse segments for Dr Trenberth displayed in Figures 16(a)-(b), indicates a certain consistency and concentration of this particular pattern type in Mr Ebell's contributions to the interview. Mr Ebell communicates most of his information during the middle segment of the video with little rebuttal from Dr Trenberth, and the consistency and concentration of a particular pattern contributes to the degree to which Mr Ebell is seen to dominate the interview, particularly in comparison to Dr Trenberth, whose speaking turns are shorter and more varied. The SFT multimodal frameworks for linguistic and image/video analysis are used to investigate the impact of Mr Ebell's pattern of selections and his perceived dominance during the interview.

The common units are 'Interactive Meaning' and 'Process' for both speakers, with sub-categories which are 'Interactive Meaning: Involvement', 'Interactive Meaning: Equality' for Mr Ebell, and 'Interactive Meaning: Representation Power' and 'Interactive Meaning: Detachment' for Dr Trenberth. Thus, the significant pattern for Mr Ebell in terms of interactive meaning is his direct engagement with his audience,

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[1] Relevant clause numbers have been inserted above each unit to map them back to the actual text. Units of video annotation do not have clause numbers inserted.

[2] In the visualizations, each unit is labeled with three pieces of information: the initials of the speaker or annotation strip name, the first three alphanumeric characters of the actual text and the first three alphanumeric characters of the annotated semiotic choice label.

whereas Dr Trenberth choices make him appear detached from his audience, though supposedly in an elevated position of power, given the low camera angle, as displayed in Figure 17(a)-(b). There is, to some extent, editorial bias in this portrayal of the two men, with a Skype format for Dr Trenberth versus the professional studio setting for Mr Ebell. However, it can be argued that both men have equal opportunity to arrange and organize their interviews. The settings give an indication as to which interviewee is more attuned to the significance of media appearances.

Figure 17(a) Screenshot of Myron Ebell

Figure 17(b) Screenshot of Kevin Trenberth

The other choices which are significant for Mr Ebell are ‘Conceptual Representation:

Attributive' and 'Gaze and Kinetic Action Vectors: Engaged'. The same choices for Dr Trenberth are not robust and frequent enough to be highlighted. From these patterns, we may see how Mr Ebell portrays a consistent and impactful visual impression where he establishes rapport with his audience and projects a credible image foregrounded against a background of Capitol Hill in Washington DC.

These video annotation units appear with the linguistic units of 'Process' for verbs or verb phrases. The 'Process' relates participants and circumstances in the clause (Halliday and Matthiessen 2004), in this case for 'Material' and the 'Relational' process types. The Material process concerns an action or happening, while the Relational process is concerned with states of being and making sense of the world by relating concrete and abstract concepts to each other. Mr Ebell and Dr Trenberth both select Relational processes most often (41.2% and 46.2% respectively). They both also select Material processes (27.9% and 19.2%) as the next most frequent choice, with a higher relative occurrence for Mr Ebell.

The clauses in which Mr Ebell and Dr Trenberth select Relational and Material process reveal a focus on what the *climate scientists* are (or are not), and what they have done (or have not done). However, even though both interviewees are focusing on the same participants and their actions, the resultant effect is different. For Mr Ebell, the focus on the actions of climate scientists functions to position him as an accuser who questions and challenges the moral standards of the climate scientists by focusing on the ethics of their actions, characterizing them as immoral individuals. He conveniently associates Dr Trenberth with this group – though he does remark that Dr Trenberth is "not one of the, sort of, main gang leaders" here, with surprisingly little verbal response from Dr Trenberth himself, apart from an initial reaction of surprise and a wry smile. Mr Ebell is then given the freedom to accuse this group, and consequently, Dr Trenberth, of intentionally giving an inaccurate picture of what is really happening with the earth's climate, with once again little intervention from Dr Trenberth other than for brief moments before he launches into an almost desperate attempt to insert as much information denying Mr Ebell's accusations as the interviewer Jon Scott attempts to close the interview.

On the contrary, Dr Trenberth's strategy of focusing on the climate scientists and their actions puts him on the defensive, given the previous media reports and online information which focus on the seemingly incriminating evidence from the emails of scientists manipulating data, playing 'tricks' and restricting access to information. Thus, the onus is on Dr Trenberth to disprove these assertions, rather than on Mr Ebell to prove the correctness of his assertions. Dr Trenberth's focus on himself and his contemporaries puts him on the defensive because he does not provide any evidence to counter Mr Ebell's attempts at character-assassination, other than to say the opposite of what Mr Ebell is saying, or worse, to even admit that what Mr Ebell is alleging might be true, except that he himself is not guilty.

In addition, Dr Trenberth's failure to respond adequately and forcefully to Mr Ebell who develops his argument in his longest utterance spread across slightly more than forty clauses, gives Mr Ebell the dialogic space to state his case freely, and thus allows him to dominate the discourse. Clayman and Heritage (2002) have defined the interview genre as akin to gladiatorial combat between interviewer and interviewee. We posit that this combat exists between two interviewees who represent different views on the same topic. Thus, Dr Trenberth's reluctance or inability to wrest dialogic space from Mr Ebell allows him time and opportunity to forcefully advance his argument, which Dr Trenberth ultimately fails to counteract for two reasons. Firstly, the news debate interview genre assigns overall authority to an interviewer who has most control over how the interview develops, and the interviewer here does not give Dr Trenberth much opportunity to refute Mr Ebell's arguments. Secondly, Dr Trenberth does not attempt to attack Mr Ebell's credibility except when he says 'Well, that's certainly a shameful comment' and 'Your charges are just completely false'. But even then, he either does not continue from there or merely continues to claim the opposite of what Mr Ebell has said. Mr Ebell renders such challenges ineffective because he has already established doubt about Dr Trenberth's credibility and made explicit what these climate scientists have done to give an inaccurate picture of the dangers facing the world as a result of global warming.

3.5 Mathematical Modeling of SFT Base Data

Using mathematical modeling, we see how the resulting visualizations of the SFT multimodal base data differ for the two interviewees. By relating these visualization patterns to the text and applying SFT frameworks, we have provided a comprehensive account for why Mr Ebell seems to have been successful in this interview. The benefit of the mathematical modeling techniques is that the patterns which emerge correspond with expectations derived from SFT multimodal base data, as corroborated by an expert human analyst. Thus the approach can be seen as a meaningful scientific methodology that employs a simultaneous top-down contextual view and bottom-up grammatical view to interpret semantic patterns in multimedia data.

In summary, our analysis has shown how the visual disengagement of Dr Trenberth, together with his linguistic and content choices and inability to take action to effectively challenge Mr Ebell when necessary, make for a less impactful and convincing argument, as compared to that of Mr Ebell, who is visually more engaging and shows his understanding of the news debate interview genre by not relinquishing his hold on the dialogic space of the interview, as long as it is not demanded by the interviewer, who is normally recognized as the institutional authority with regard to how the interview is conducted (Budd, Craig and Steinman 1999), and by using efficiently whatever time he has been given to put forward his arguments.

It is clearly not facts and reputation that help to win over an audience in a news debate interview. This is apparent in how Dr Trenberth, even with his knowledge about climate change and his credibility as a Nobel prize-winning scientist, ends up desperately trying to regain ground towards the end of the interview. Perhaps, because of the visual nature of the television news debate interview, the *person* takes centre stage, where credibility is not established through logical argument or one’s reputation, but through a populist yardstick based on information that is easily accessed and repeated endlessly in a public domain by media that may prioritize one particular perspective over another as a result of its own agenda – news reports that sell (Weingart, Engels and Pansegrau 2000) and a visual accessibility that attracts attention and positive evaluation from viewers.

Thus, our methodology of combining mathematical modeling and SFT multimodal analysis has shown two advantages: one, that there is a way to objectively combine the overwhelmingly numerous linguistic and visual choices made in a multimedia text and make sense of these seemingly disparate choices over the dimension of time; and two, that the patterns derived via mathematical modeling and its resultant visualizations can be interpreted through theoretical frameworks that imbibe these patterns with meaning. Moreover, the interpretations arising from the analysis can help us understand more about the ideological implications of digital communication today.

4. Future Work

"To say we move in a new world, the digital information age, is already a cliché. Our challenge appears to be the navigation through and adaptation to not so much an actual, material environment but the virtual semiotic, informational environment— an environment of our own making, incorporating the discourses of many millions of multiliterate social agents; and yet an evolved rather than designed environment" (O'Halloran & Smith, in press).

The project has reinforced and extended existing research findings concerning the communication of climate science in the public domain, showing how the media plays a powerful role in influencing how members of the public perceive both scientific knowledge and the scientific community itself (Boykoff and Boykoff 2004; Boykoff 2011; Carvalho 2007). We have also demonstrated how mathematical modeling of SFT multimodal data can contribute to our understanding of how events are construed and reported by different text producers. Such a methodology can be extended to any domain of private and public activity. In this project, we chose the financial crisis and climate change due to the global significance of these events in the world today.

The techniques developed in this project point to the future for data analysis, search and retrieval as an integral component of visual analytics software for social cultural modeling. With the perpetuation of such trends and the instantiation of instabilities being carried through modes of communication made easy and more diverse in an increasingly advanced digital age, we need to critically examine instances of human communication in its various multimodal forms to make sense of how societies and cultures maintain and perpetuate the very ideas, beliefs, values and principles which drive their very existence. Mathematical modeling multimodal communication will enable us to understand the increasingly complex and dynamic world we now live in, with view to identifying and tracking evolving semantic patterns, in particular those related to stability and instability in a rapidly changing world which is facing many immediate challenges. Future work in the Multimodal Analysis Lab will focus on developing more sophisticated mathematical modeling approaches with view to integrating these techniques in existing visual analytics software for socio-cultural modeling.

5. List of Publications

Research Papers

[1] E, Marissa K. L., O’Halloran, K. L. and Judd, K. (2011). Working at Cross-Purposes: Multiple Producers and Text-Image Relations. *Text and Talk*, 31(5), 579-600.

[2] Smith, B. A., O'Halloran, K. L. and E, Marissa K. L. (submitted for publication). Dynamics in Spoken Discourse and the Co-Construction of Text: Textual Systems. *Functions of Language*.

[3] O’Halloran, K. L., Podlasov, A., Chua, A. & E, Marissa K. L. (in press 2012): Interactive Software for Multimodal Analysis. In J. Holsanova (Ed.), *Multimodal Methodologies*. Special Issue of Visual communication, August 2012, 11:3. Sage.

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